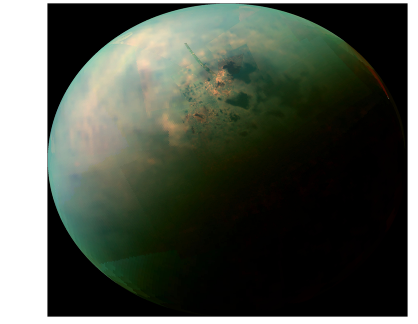
Electrical Breakdown and Dissipation in Titan's Atmosphere



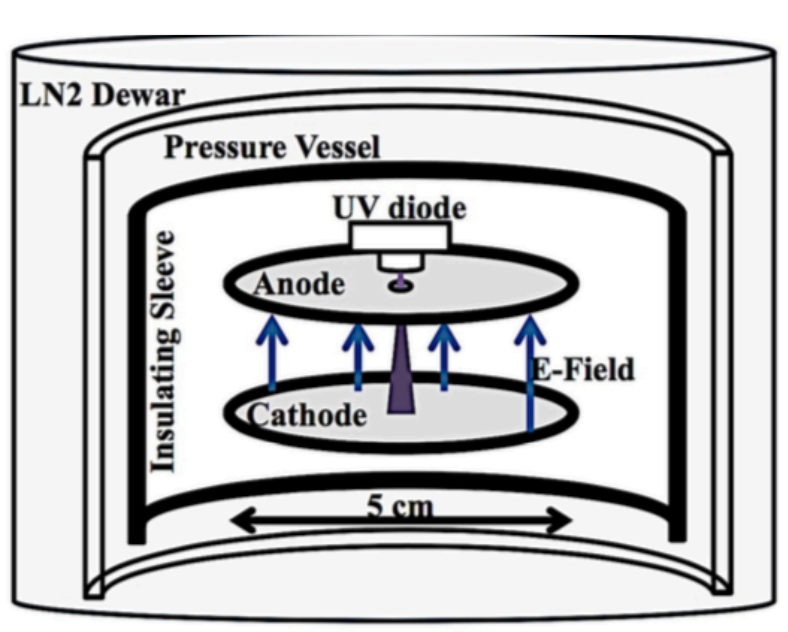
William Farrell[1], Jason McLain[2], and John Marshall[3]

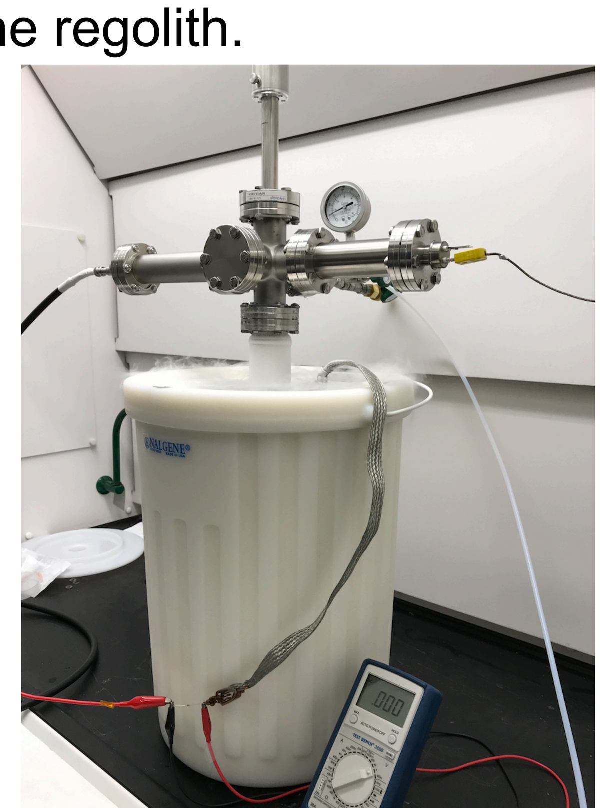
1. NASA/Goddard Space Flight Center, Greenbelt, Maryland; 2.CRESST University of Maryland, College Park, MD; 3. SETI Institute Mountain View, CA

How does the unusual electrical conductivity of Titan's lower atmosphere affect systems that charge up, like saltating grains in the dunes and roving robotic systems? We will develop an atmospheric electricity model of Titan's lower atmosphere to understand the nature of the dissipation to any charge build-up.

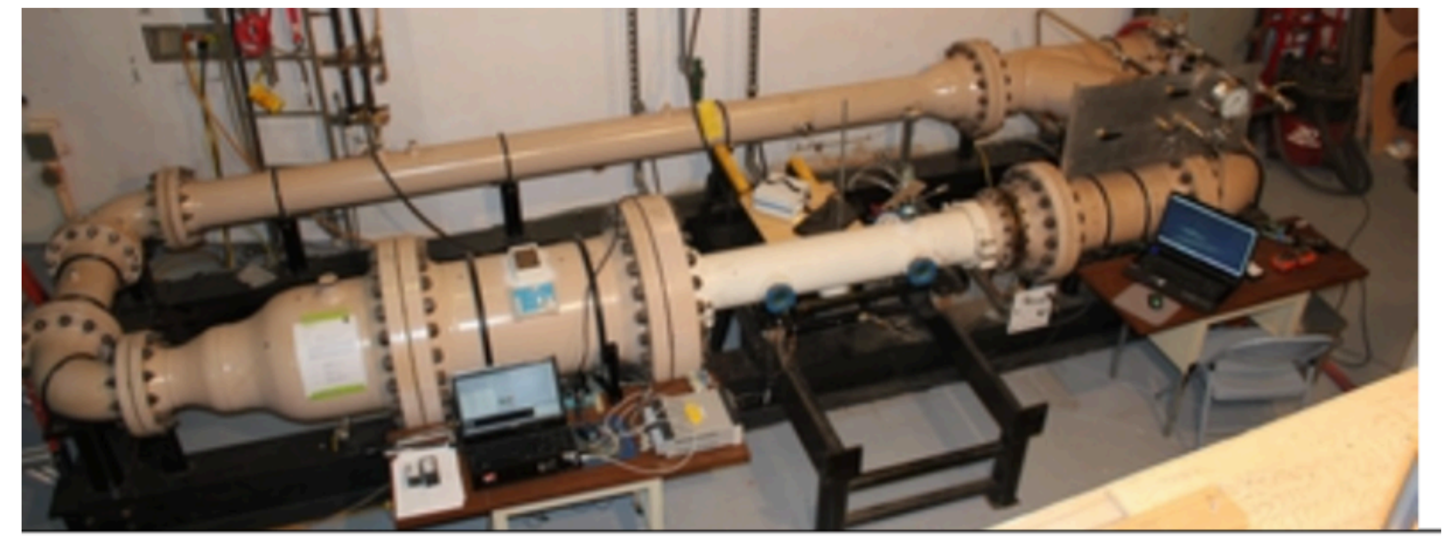
Motivation: While the nitrogen-rich, high pressure atmosphere at Titan has some similarities to the terrestrial atmosphere, there is a very significant difference: the atmospheric electrical conductivity. Specifically, the electron conductivity greatly exceeds the positive ion conductivity possibly by many orders of magnitude [Molina-Cuberos, 2001]. This unusually high electrical conductivity decreases electrical charge dissipation times, removing charge from atmospheric storms, triboelectrically charging saltating grains, and roving robotic systems.

Objectives: We will examine the details of the gas breakdown process to develop an atmospheric electricity model for Titan (similar to that for Earth [Volland, 1984] and Mars [Farrell and Desch, 2001]). Possible applications including explaining the lack of lightning from the moon, quantifying the grain tribo-electric processes in the Titan dune fields, and placing expectations for rover system chargingduring movement over the regolith.

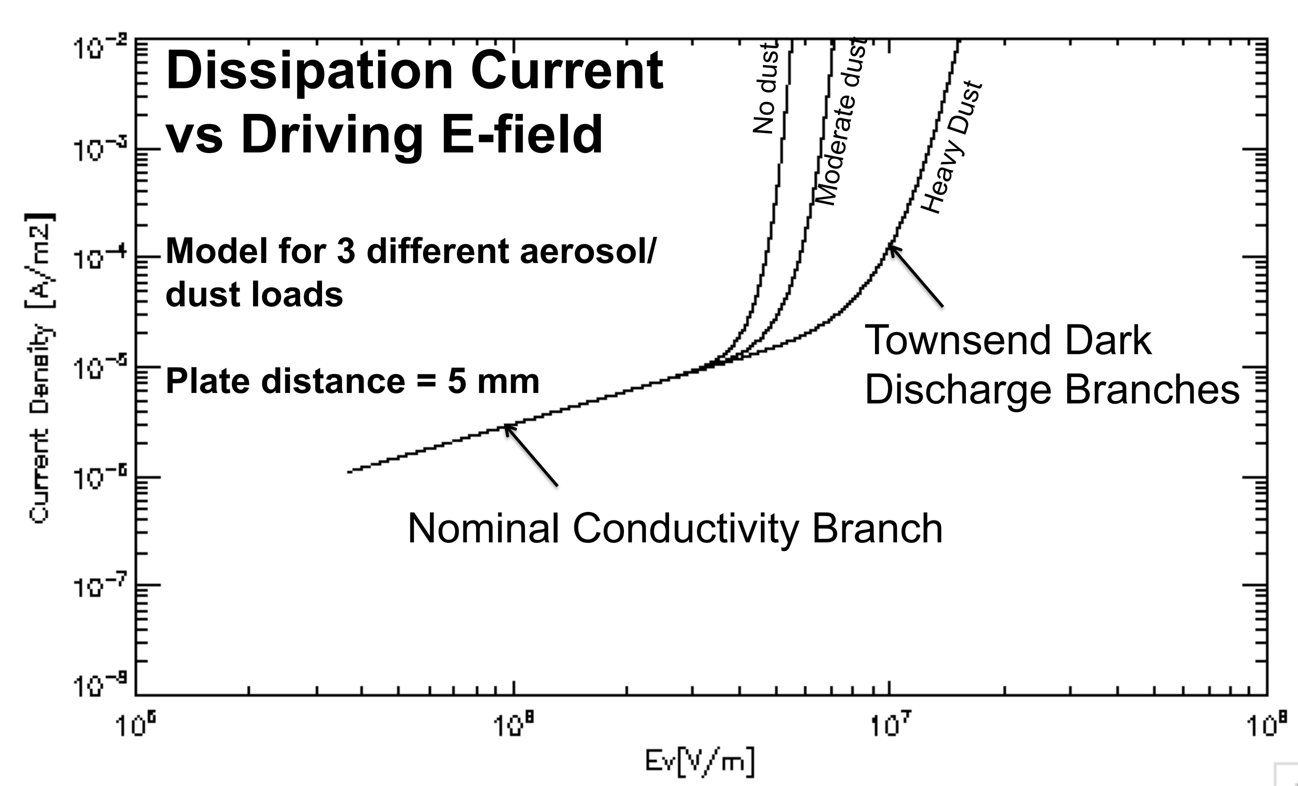




The build of a Titan Atmosphere Breakdown Chamber. We have designed and built a Titan atmosphere breakdown system. In the chamber, two plates are immersed in a Titan-like atmosphere and the voltage is varied on the plates to examine the transitions from nominal atmospheric conductivity, to Townsend Dark Discharge (the pre-spark exponential growth of electrons), to the spark breakdown condition in the gas. In this first year, the novel chamber was built and continues to be tested.



Titan Wind tunnel at the Planetary Aeolian Facility at NASA/AMES. This system is a pressurized close circuit tunnel (operable up to 20 bar). Internal gas is driven around the circuit by a fan mounted in the back right corner. Saltation test beds are laid on a flat plate that is about 6 cm height in the tube system. This is an existing facility but we will add electrical sensing devices (electrometers and radios built at GSFC) to examine the nature of the tribo-electric charge build up in saltating grains − which is a potential source of electricity [Mendez Harper et al., 2017]. We will merge this electrical source with our dissipation models from the breakdown experiments at GSFC.



Development of Models of Gas Breakdown in Titan's Atmosphere: In the first year, we also developed a model of the breakdown process for comparison to our breakdown experiments. At low E-fields, the gas initially has nominal conductivity ($J = \sigma E$) where currents are proportional to the driving E-field. However, as E increases, the currents increase exponentially due to increased electron impact ionizations. This regime is called the Townsend Dark Discharge. We also include the effect aerosols/dust have on the conductivity. Dust will absorb electrons from the gas, reducing the dissipating Townsend Dark Discharge. A larger E-field is then required to initiate the Townsend effect.

Example Application of a Titan AE model: Titan Dune Fields. Mendez-Harper [2017] and the team at Ga. Tech have suggested that saltating grains in Titan's dune fields creates E-fields that then alter dust trajectories. Using the Ames facility, we can estimate the tribo-charge build up for saltating grains. Then, using the results of our lab and model breakdown studies, we can estimate the associated dissipation currents that will limit the tribo-electric charge build-up. Knowledge of the entire electrical environment is required to examine such an electrically-dynamic system. Also, the exposure of tholin-like material to electricity may alter the surface chemical state, and this new angle of our work will be pursued with support from other FLARE teams.

Example Application of a Titan AE model: Human System Charging. As a rover moves over regolith, the wheels will tribo-charge. However, this rover charge build-up is offset by the dissipation of the charge back into the Titan atmosphere. The figure below illustrates the simple equivalent circuit. The rover can be considered a capacitor, C_{rover}, collecting tribo-charge as it roves, developing a potential difference, V_{trib}, between the rover and ground. This tribo-charge can trickle back into the ground or be dissipated into the atmosphere. The dissipation current into the atmosphere, I_{Atm}, is a function of the near-rover E-field (see adjacent plot). Given our new AE model, we can predict the equilibrium charged state of the rover by equating tribo-charge sources to the atmospheric dissipation current, $I_{atm.}$ This application will be carried out in year 2 of our study.